Technology: Changing the Game
- Impacts of Technological Changes in the Cyber Environment on Software/Systems Engineering Workforce Development

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Overview

• Perspective
• The Problem Space
• Software and Systems Engineering Issues
• The Human Element
The ability of organizations to compete will increasingly depend on the innovation of the human element.
Cyber Security Landscape

Stakeholders recognize the importance of cyber infrastructure to our nation's prosperity.

• Public and private sector enterprises today are highly dependent on information systems to carry out their missions and business functions.

• To achieve mission and business success, enterprise information systems must be dependable in the face of serious cyber threats.

• To achieve information system dependability, the systems must be appropriately protected.

Source: “Information Systems Under Attack”, NIST

What is at risk?

Transportation Infrastructure + Healthcare Infrastructure + Banking & Financial Infrastructure + Energy & Utilities Infrastructure + Communications Infrastructure

“…I’ll make cyber security the top priority that it should be in the 21st century… coordinate efforts across the federal government, implement a truly national cyber-security policy, and tighten standards to secure information…”

President Barack Obama
Overview

• Perspective
• The Problem Space
• Software and Systems Engineering Issues
• The Human Element
Imperatives

• DDR&E Imperatives*
  – Accelerate delivery
  – Uncertain future
  – Reduce the cost, acquisition time and risk
  – Develop world class STEM **

* The Honorable Zachary J. Lemnios, DDR&E
** Science, Technology, Engineering and Mathematics Capabilities
Four Key Challenges to our Technical Base

- **DoD**
  - Shift in Technical Talent Base

- Commercial

- **Time**

- **Foreign**
  - Global Access to Technology

- **Tech Areas**

- **Technical Talent**
  - Shift in Technical Talent Base

- **Foreign**

- **Time**

- **Increasing Pace of Innovation**

Source: DDR&E
DON Systems Engineering Hierarchy

DON = Department of Navy

Mission
- Frame Focus

SOS Platform / Net Centric
- Capability Focus

System
- Functional Focus

Component
- End Item Focus

Translates:
- Operational Concepts → Mission Capabilities
- Mission Capabilities → System Requirements
- System Requirements → Component Functions
- Component Functions → End Items

DON = Department of Navy
An Effective Process for Major Defense Systems – But Not Very Agile
Defense Acquisition Approach
- Systems Engineering is Key Discipline

70-75% of Cost Decisions Made Prior to Milestone A
Impact 72% of Total Life Cycle Costs

Source: DDR&E
Need for Space, Air, Ground, Water, Underwater Software-Intensive Systems that are Interconnected

- Several million SLOC programs; “Hybrid” systems combining legacy re-use, COTS, new development
- Multi-contractor teams using different processes; dispersed engineering, development & operational locations
- New technologies create opportunities/challenges; products change/evolve, corporations mutate
- Business/operational needs change - often faster than full system capability can be implemented
- Skillset Shortfalls; Cost and schedule constraints
- Demands for increased integration, interoperability, system of system capabilities
- Enterprise perspectives/requirements; sustainment concerns

Development Complexity of Software-Intensive Systems is Increasing
Software Development Schedule Trends

#Years ~ 0.4 * cube root (KSLOC)

- Delaying software start increasingly risky
- Need to find ways to compress software schedules
- Timeboxing; architecting for decoupled parallel development

Ref: Barry Boehm
Realities of Software Quality

The flowchart might correspond to a 100 LOC module with a single loop that may be executed no more than 20 times.

There are approximately $10^{14}$ possible paths that may be executed!

For any but the smallest programs, complete path coverage for defect detection is impractical.

Technological: Rate of Adoption
The Cyber Domain is Hotly Contested

Sophistication of Available Tools
- cross site scripting
- "stealth" / advanced scanning techniques
- denial of service
- automated probes/scans
- GUI
- distributed attack tools
- www attacks

Sophistication of Required of Actors
- network mgmt. diagnostics
- hijacking sessions
- exploiting known vulnerabilities
- sweepers
- sniffer
- packet spoofing
- back doors
- disabling audits
- burglaries
- password cracking
- self-replicating code
- password guessing

Increased GIG Complexity & Dependence equates to lower entry barriers and potential for increased number of malicious actors

Defensive measures are outpaced by the well resourced sophisticated threat
Overview

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Increasingly, urgent demands of the warfighter are requiring effective capabilities to be fielded more rapidly than the conventional acquisition processes and development methodologies allow.

The quantity and quality of Systems Engineering expertise is insufficient to meet the demands of the government and defense industry.

Systems engineering practices known to be effective are not consistently applied or properly resourced to enable early system definition.

Technical decision makers do not have the right information & insight at the right time to support informed & proactive decision making to ensure effective & efficient program planning, management & execution.

The development of systems with a full level of integrity (all technical aspects considered) is longer and more expensive over the entire lifecycle as the technical solution is iterated and reworked in later stages of the development.
Top Software Engineering Issues - 2010

- The increasing demands of the war fighter are requiring development of software and systems more rapidly than acquisition models and development processes allow.
- Inadequate/insufficient program planning and start-up has a negative exponential impact on the program’s software success.
- For complex systems and systems-of-systems, software engineering practices are not well defined.
- There is insufficient attention given to the overall software life cycle activities including sustainment and changing threats.
- Fundamental system engineering decisions are made without full participation of software engineering (2006 carry over)
  - Education programs do not adequately address need for software engineering to be involved throughout the acquisition process.
Software Engineering Trends

- Software engineering will become increasingly vital to DoD, government, and commercial operations.
- Software will become increasingly complex and connected.
- New technical, governance, and process concepts are needed to handle increasing complexity and decentralization.
- Software and systems engineering architectures are vital to the development, evolution, and sustainment of future systems.
- Increasingly complex and connected systems need to be architected for security and for operational resiliency.

Source: SEI
What Makes Software Engineering Different?

- Essential Properties of Software differentiate it from other kinds of engineering artifacts
  - Software Invisibility
    - No physical properties
  - Complexity
    - Effort/expense required to construct it for their size
  - Conformity
    - Must conform to exacting specifications
  - Software Changeability
    - Most frequently changed element
# Cyber Engineering Compared with other Sciences

<table>
<thead>
<tr>
<th></th>
<th>PHYSICAL SCIENCE</th>
<th>BIOSCIENCE</th>
<th>SOFTWARE/CYBER ENGINEERING</th>
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<tr>
<td><strong>Origins/History</strong></td>
<td>Begun in antiquity</td>
<td>Begun in antiquity</td>
<td>Mid-20\textsuperscript{th} Century</td>
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<tr>
<td><strong>Enduring Laws</strong></td>
<td>Laws are foundational to furthering exploration in the science</td>
<td>Laws are foundational to furthering exploration in the science</td>
<td>Only mathematical laws have proven foundational to computation</td>
</tr>
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</table>
| **Framework of Scientific Study** | Four main areas: astronomy, physics, chemistry, and earth sciences | Science of dealing with health maintenance and disease prevention/treatment | • Several areas of study: computer science, software/systems engineering, IT, HCI, social dynamics, AI  
  • All nodes attached to/relying on netted system |
| **R&D and Launch Cycle**   | 10-20 years      | 10-20 years | Significantly **compressed**; solution time to market needs to happen very quickly |
Overview

• Perspective
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• The Human Element
At What Level Should the Integration of Systems and Software Engineering be Taught?
Refocusing University Curriculums: Alignment of Software and Systems Engineering

OSD Initiatives: Graduate Software Engineering Reference Curriculum (GSwERC) & Body of Knowledge and Curriculum to Advance Systems Engineering (BKCASE)
Moore's Law: The Number of Transistors That Can be Placed on an Integrated Circuit is Doubling Approximately Every Two Years
Augustine’s Law: Growth of Software - Order of Magnitude Every 10 Years

In The Beginning

1960’s
F-4A
1000 LOC

1970’s
F-15A
50,000 LOC

1980’s
F-16C
300K LOC

1990’s
F-22
1.7M LOC

2000+
F-35
>6M LOC

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Trend & Implications: Augustine’s Law Will Hold

2080?

F-50 - 4.7B Lines of Code

Need for increased functionality will be a forcing function to bring the fields of software and systems engineering closer together.
Human Capital: Society Drivers

Rebalanced Workforce

AT&L Civilians

Bimodal Demographics (Space Industry)

Professional Growth vs. Time

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Human Capital: Society Drivers

Notional DoD Systems Engineering Workforce Strategy

- Develop / Train: Mentors
- Recruit: Highly Qualified Experts

Recruit:
- Interns
- Journeymen
- Retired Military
- SE FFRDCs

Develop / Train:
- Size

Workforce Age

Workforce Size

25-35
35-45
45-55
>55

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Human Capital: We are in a Competition for the Best Technical Talent

Thousands of graduates

Source: The Honorable Zachary J. Lemnios
Director, Defense Research and Engineering

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Human Capital: Using Core Competencies

Accurate identification of required competencies are important to support the curriculum review and development effort needed to ensure the best and most relevant training.

<table>
<thead>
<tr>
<th>Workforce Competency</th>
<th>Staffing by Capacity Level</th>
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<tbody>
<tr>
<td>Software Engineer</td>
<td>1  2  3  4</td>
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<tr>
<td>User Training</td>
<td>2  8  4  1</td>
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<table>
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<tr>
<th>Workforce Competency</th>
<th>Current Staffing Level Needed</th>
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<tr>
<td>Software Engineer</td>
<td>23  30  15  7</td>
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<tr>
<td>User Training</td>
<td>4   9   6   2</td>
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<th>Strategic Workforce Needs (2-5 year)</th>
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Human Capital: Changing Demographics

Demographics of workforce are changing and different views may emerge with four generations to consider.

Generation Y professionals entering workforce will likely necessitate non-traditional training techniques, such as virtual approaches.

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<tr>
<td>Hard worker</td>
<td>Workaholic</td>
<td>Technically advanced</td>
<td>Technically savvy</td>
</tr>
<tr>
<td>Respects authority</td>
<td>Questions authority</td>
<td>Prefers informality</td>
<td>Embraces diversity</td>
</tr>
<tr>
<td>Work is obligation</td>
<td>Works efficiently</td>
<td>Needs structure and direction</td>
<td>Requires supervision</td>
</tr>
<tr>
<td>Formal communicator</td>
<td>Competitive</td>
<td>Direct/Immediate communicator</td>
<td>Indirect/virtual communicator</td>
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<tr>
<td>Work/family separation</td>
<td>Little work/life balance</td>
<td>Seeks work/life balance</td>
<td>Demands work/life balance</td>
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In the Current Cyber Environment, We Must Fully Engage the Software/Systems Engineering Workforce

• Complexity
  • Scope & Scale: number and diversity of elements
  • Connectivity: interdependencies among the disparate elements
  • Emergent behaviors: nonlinear stochastic response functions
  • Effects of non-technical attributes and characteristics

• Criticality
  • Systems to be continuously available
  • Able to deal with Security, Privacy, Authenticity, Accuracy, requirements “seamlessly” & without performance degradation

• Compatibility
  • Integrate the newest/fastest with the oldest/slowest

• Chronology
  • “Idea” to “IOC” measured in weeks/months versus years/decades

• Competency
  • Can the workforce develop the knowledge and abilities to adapt & survive?

Source: DDR&E
Questions?